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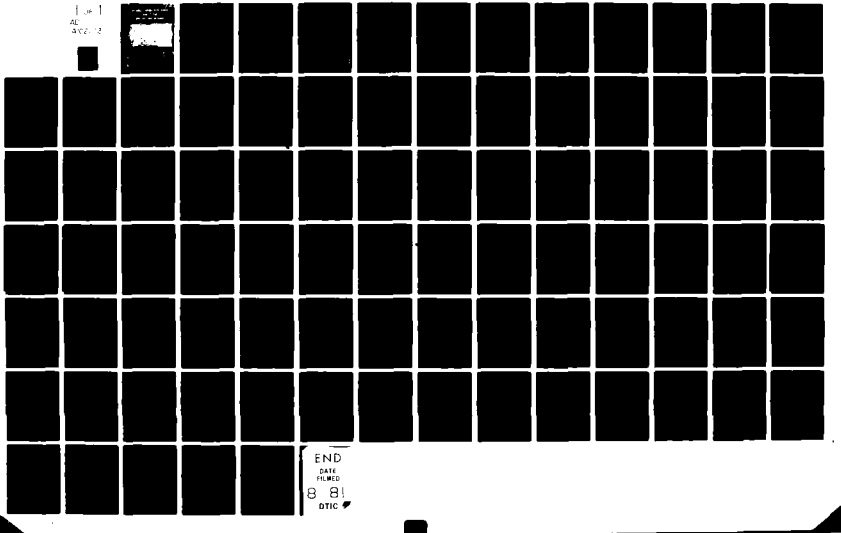

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NATIONAL ECONOMIC DEVELOPMENT BENEFITS FOR NONSTRUCTURAL MEASURES

OCTOBER 1980

THE HYDROLOGIC ENGINEERING CENTER
U. S. Army Corps of Engineers

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The purpose of this document is to assist Corps of Engineers field office personnel in evaluation of NED benefits for nonstructural measures by use of economic concepts, interpretation of regulatory procedural documents and numeric examples. The report is intended to be used as a guide in NED benefit analysis studies of nonstructural measures. It describes the applicability of different benefit classifications (inundation, intensification and location) with respect to implementation of various (CONTINUED)

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nonstructural measures. Narrative examples and summary tables for quick reference are contained in the main body of the text and numeric examples displaying simplified computations are contained in an appendix.

NATIONAL ECONOMIC DEVELOPMENT BENEFITS FOR NONSTRUCTURAL MEASURES

October 1980

The Hydrologic Engineering Center
U.S. Army Corps of Engineers
Davis, California

FOREWORD

National economic development (NED) benefit evaluation of nonstructural measures is presently a significant and integral part of the federal planning process of flood mitigation investigations. The NED benefit evaluations of structural measures (primarily measures designed to control flood events and implemented on a broad scale) have generally been adequately performed since the early involvement of the federal government in flood control projects in the 1930's. Emphasis of nonstructural measures (permanent or temporary modification of existing or future damage susceptability on a localized scale) has resulted primarily from an emerging environmental awareness and subsequent federal executive and legislative actions of the past decade. This relatively recent emergence, broad scale nature of measures and localized implementation of nonstructural alternatives has enerated an expressed need from Crops field offices for more explicit interpretation of regulatory documents and procedures for nonstructural, NED, benefit evaluations in conducting flood mitigation studies.

The purpose of this document is to assist Corps of Engineers field office personnel in evaluation of NED benefits for nonstructural measures by use of economic concepts, interpretation of regulatory procedural documents and numeric examples. The report is intended to be used as a guide in NED benefit analysis studies of nonstructural measures. It describes the applicability of different benefit classifications (inundation, intensification and location) with respect to implementation of various nonstructural measures. Narrative examples and summary tables for quick reference are contained in the main body of the text and numeric examples displaying simplified computations are contained in Appendix C.

Preparation of the report was performed by William D. Carson, Chico, California, under contract to the Hydrologic Engineering Center (HEC), Corps of Engineers. Michael Burnham, Planning Analysis Branch, HEC, was responsible for managing the study under the general guidance of Darryl W. Davis, Chief, Planning Analysis Branch, HEC. Bill S. Eichert was Director of the Hydrologic Engineering Center during the preparation of the report.

Others who provided input to material presented include: Paul Seguin of the St. Paul District; Ed Cohn, Office of Chief of Engineers and Ed Dickey, Secretary of the Army Office. Bill Johnson, Planning Analysis Branch, HEC, provided many useful comments and suggestions. Paul Gaudini, Philadelphia District; Joe Mantey, Los Angeles District; and Ed shiffers, Board of Engineers, Rivers and Harbors, each provided important comments during the review of the draft report.

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SECTION 1
INTRODUCTION

Purpose

Primary objectives of floodplain management plans are national economic development and enhancement of environmental quality. The purpose of this report is to clearly define national economic development (NED) benefits and to illustrate the calculation of these benefits for nonstructural flood mitigation measures. Emphasis is on evaluation and not formulation of plans. Methods and procedures suggested in this report are based on economic theory and appropriate Corps documents. Different stages of a flood mitigation study will apply the evaluation procedures with different levels of detail (Corps of Engineers, 1975).

Section 73 of the Water Resources Development Act of 1974 requires nonstructural alternatives be considered as measures to prevent or reduce flood damage. Further emphasis on nonstructural alternatives is provided by a Presidential Memorandum of July 12, 1978 and Executive Order 11988 (Carter, 1977). Nonstructural measures have been defined in various ways. For example, "nonstructural alternatives for flood damage prevention can be defined as those alternatives that involve avoidance of flood damages rather than confining the flood waters" (Corps of Engineers, Fort Worth and Galveston District, 1979). ER 1105-2-122 defines nonstructural measures as:

> "(a) 'Structural measures' are physical measures which act directly on riverine or tidal waters to change their direction, area of inundation, volume, stage or timing to reduce flood damages or to enhance the value of the floodplain.
> (b) 'Nonstructural measures' are all other actions, including floodproofing, designed to reduce or avoid flood damages, or to enhance the value of the floodplain." (Corps of Engineers, 1979) This definition is not very informative for the planning process.

Here nonstructural measures are defined as those measures which fall into

one of three categories. The first includes measures which permanently modify the damage susceptibility of existing structures; for example, raising or relocating a structure reduces or removes its damage susceptibility. The second includes measures which reduce damage by management of future development; for example, public acquisition of floodplain land preserves flood compatible use. The third includes the components of flood preparedness plans; for example, flood recognition, warning and emergency response action which reduce flood damage. Flood insurance may be included as a measure which manages future development but since it does not create NED benefits but indemnifies losses it is not discussed further in this report.

It should be noted that many nonstructural flood mitigation measures have been implemented at the state and local level. Zoning and other regulatory policies to manage land use are widespread. Most flood prone communities have a flood preparedness plan although these vary widely in extent and sophistication. Finally, some existing structures have been floodproofed or elevated to reduce damage susceptibility.

Types of NED benefits will be defined and their applicability to the nonstructural measures within each category will be discussed in the following chapters. Emphasis is on providing a conceptually sound basis for determining the benefits of nonstructural flood loss mitigation measures. Procedural aspects of benefit estimation will be illustrated by presentation of numerical examples in Appendix C. The examples will be illustrative rather than exhaustive. Although this report deals only with NED benefits, benefits from enhancement of environmental quality should not be overlooked in evaluation of a flood management plan.

Categorization of Nonstructural Measures

A number of nonstructural measures have been identified (Johnson, 1978). Some of the measures are similar enough to be grouped or categorized. Grouping of measures into a small number of categories is helpful for the planning process because a more balanced assessment of a broader group of actions is possible.

The categorization allows evaluation procedures appropriate to each category of measures to be identified. The categorizations chosen for this report also encourage balanced treatment of measures which may have differing lives or which may affect future conditions as well as existing conditions. By having specific categories the fact that different kinds of measures exist is also highlighted.

So, for planning purposes, the measures are grouped into three categories (James, 1975; Davis, 1976): 1) measures which permanently modify the damage susceptibility of existing structures; 2) measures which manage future development in terms of both location and damage susceptibility; and 3) measures which are part of a flood preparedness plan. The following paragraphs briefly describe the three categories of measure. More detailed discussion is included in the individual sections.

Measures Which Permanently Modify Damage Susceptibility of Existing Structures. Several nonstructural measures permanently modify the damage potential of structures which exist in the floodplain. That they are permanent implies that the effectiveness of the measures does not depend on flood warning and response. This is a key distinction between this category and flood preparedness plan measures which are temporary.

Measures which reduce damage susceptibility fall into two subcategories: 1) permanent floodproofing; and 2) permanent relocation of people, property and/or structures. Floodproofing measures include those which protect the structure and its contents by excluding water, i.e., closures and seals, raising the structure, and perimeter barriers. These measures reduce damage at each stage of flooding until the design level is exceeded. The stage damage relationship then resumes its original or a slightly modified position. Floodproofing also includes actions which modify the use of a structure to reduce damage susceptibility, i.e., rearranging the contents of a structure, restricting use of lower floors and protecting damageable contents such as appliances and utilities. Both types of floodproofing require site and structure specific analyses--all structures within the floodplain need to be examined and specific measures evaluated.

Permanent relocation modifies the damage susceptibility of existing structures by removing the structures and contents from the floodplain. A specific regulation, ER 1105-2-353 (Corps of Engineers, 1978), has been developed to define formulation and evaluation of the relocation alternative. This regulation and the Water Resources Council Procedures (Water Resources Council, 1979) define how damage reduction can be evaluated for evacuation. This is discussed in detail later in this report. Relocation is included in this category for consistency of planning and evaluation tasks--the measure permanently modifies the damage susceptibility of existing structures.

Measures Which Manage Future Development. Managing future development reduces flood losses by either discouraging potential activities from locating where they are likely to incur damage or by requiring that structures which do locate in the floodplain do so in a manner compatible with the flood hazard. The management measures thus prevent the addition of flood loss potential in the future. Land use can be controlled by regulations such as: zoning ordinances, building codes and restrictions; or by purchase of land in fee or for a flood easement. Other measures which manage future land use are taxation which makes floodplain locations more expensive to develop and flood hazard information systems. Those structures which are not precluded from floodplain locations by these measures may locate on the floodplain if they are constructed and maintained to recognize the flood hazard. Measures which modify the damage susceptibility of future structures thus fall within this category. These measures may either be undertaken in response to regulatory action or in response to flood history. Regulatory action and acquisition can also bring about a new use of the floodplain. The net income of the new use either measured directly or by market value of land is a contribution to the NED objective and thus a benefit.

Flood Preparedness Plans. The final category of nonstructural measures is the flood preparedness plan. Included are measures which are undertaken immediately before, during or immediately after a flood in an attempt to reduce the losses (both physical damages and lives) which would otherwise result. Flood preparedness plans fit into overall planning for the flood event in three ways. First, the flood preparedness plan is used if other structural and nonstructural

measures are not feasible. Second, flood preparedness plans may be used as an interim measure while other measures are being authorized and built. Finally, flood preparedness plans may be used to enhance structural or nonstructural measures which do not provide adequate protection.

The components of a flood preparedness plan are: 1) recognition of impending flood; 2) dissemination of flood warnings; 3) emergency responses to the flood warning; 4) post-flood recovery; and, 5) continuous plan management even when no floods are imminent.

The specific actions taken in response to the flood warning, and the actions taken after the flood has passed, are the only measures within this category which reduce damages. Actions include: 1) emergency evacuation of people and property; 2) floodfighting (e.g., using sandbags, flashboards, etc.); 3) emergency relief; 4) repair of public utilities and facilities; and, 5) clean-up after the flood waters recede. The effectiveness of these actions is determined by a number of factors, including: length of warning time; responsiveness of floodplain occupants to the warning (e.g., weekends and nights might find people less responsive to warnings particularly if false alarms had been experienced in the recent past); and, the extent to which local resources are organized and emergency workers trained to respond to floods. A community with a well trained and practiced emergency organization and relatively long intervals between warnings and floods will be more able to respond to flood warnings and take emergency actions than one subject to flash floods which has no emergency action plan or organization.

SECTION 2
NATIONAL ECONOMIC DEVELOPMENT BENEFITS

Introduction

Economic benefits from flood loss mitigation measures are increases in net income which result from reduction of damage to or increase in revenues over costs for floodplain land uses. The general relationship can be stated as follows:

$$\text{Economic Benefits} = \text{Net Income from Damage Reduction and Net Income from Land Use} \quad (1\text{-}1)$$

Net income is defined as:

$$\text{Net Income} = \text{Revenues} - \text{Costs} \quad (1\text{-}2)$$

Floods cause losses in the form of physical damage to structures and property, emergency costs, and losses of wages or income. Floods also limit the nature and intensity of activities potentially or actually located in the floodplain. Reducing losses increases net income by reducing the cost of a floodplain activity while reducing the limits on land use may either allow increased revenue or decreased cost of an activity and thus increased net income. If floodplain users undertake actions to reduce flood losses or to increase the usefulness of the floodplain they are better off (that is, they have higher net income) as long as the cost of the actions is less than the additional income which results. The value, or benefit, of the actions is thus the increase in net income which results from the action.

The National Economic Development (NED) benefit of a flood loss reduction measure is defined to be the amount which floodplain users would be willing to pay for that measure (Water Resources Council, 1979). Measurement of the benefits assumes that users would be just willing to pay an amount equal to the increase in net income resulting from the measure whether this comes from a reduction in the value of physical damages, or from the net income increase of

an intensified or new use of the floodplain. The change in net income which results from the implementation of a flood loss mitigation plan is thus the NED benefit of that plan. A plan may also increase net income by allowing a public activity (such as recreation) which has benefits in excess of its costs to use the floodplain.

It is more appropriate in some cases to characterize benefits as the reduction in costs brought about by the plan. The result is the same, i.e., the difference between cost and revenue increases. For residential users, costs of floodplain occupancy are reduced by a flood management plan. These cost reductions contribute directly to national economic development because resources are released for production of more goods and services to be produced. Net income is increased because costs go down and revenues remain unchanged.

Three categories of NED benefits (Water Resources Council, 1979) are defined to distinguish among the different courses of action which floodplain users can take in response to a flood loss mitigation plan. The categories are: inundation reduction benefits, intensification benefits, and location benefits.

Inundation reduction benefits are flood losses reduced by a plan when the use of the floodplain is the same in the with and without condition. Intensification benefit is the increase in income to a floodplain activity which exists in both the with and without condition but which is intensified in the with condition because of a plan. Location benefit is the increase in net income to an activity which locates in the floodplain in response to the plan but which would not locate there otherwise. Benefit categories are discussed in detail with reference to the various nonstructural measures in subsequent paragraphs.

Inundation Reduction Benefits

Inundation reduction benefits are the net income increase which results from flood loss mitigation measures when use of the floodplain is the same with and without the measure. Types of inundation reduction benefits are: reduction in physical damages, savings in emergency costs, reduction in income losses of

business and reduction in certain other flood related costs (floodproofing costs reduced, reduction in flood insurance overhead and restoration of land values). These reductions contribute to the NED objective by increasing net income by either reducing the cost of floodplain occupancy or by preventing income losses or restoring land values.

Inundation reduction benefits apply to both existing and future uses of the floodplain which are the same with and without the nonstructural measure. For example, physical damage can be reduced by raising an existing structure and by requiring placement of new development above a specified flood frequency elevation per the National Flood Insurance program. In order to claim benefits, the analysis of new development must show the structures will locate in the floodplain in the future whether the flood mitigation measure is implemented or not. The criteria for this benefit is that the use of the floodplain is the same with or without the measure. In the following paragraphs each type of inundation reduction benefit is briefly discussed.

Physical Damages. An inundation reduction benefit is created when a nonstructural measure reduces or prevents damage to structures or contents, either existing or future. For example, a measure preventing water from entering a building will protect the interior of the structure and its contents. The relationship between flood stage and damage is modified and benefit is measured as the difference in damage with and without the measure.

Emergency Costs. Emergency costs are "those additional expenses resulting from a flood that would not otherwise be incurred." (Water Resources Council, 1979). These include costs of: providing a flood emergency center, of communications facilities not otherwise needed, temporary evacuation, assistance for evacuees, floodfighting materials and personnel, and the increased costs of providing police and fire protection. Reduction of emergency costs can be claimed as inundation reduction benefits only for uses of the floodplain which are the same with and without the project. Appendix B discusses the conceptual issue of emergency costs as a benefit category.

Emergency costs have no apparent functional relationship to physical damages and cannot be estimated using an arbitrary percentage of physical damage. Estimates of emergency costs must be based on the characteristics of the floodplain, its uses, the pattern and extent of occupancy, and its accessibility. These estimates must be based on specific survey or empirical research (Water Resources Council, 1979). For example, historic emergency costs could be related to depth of flooding, type and density of urban development and etc. Showing that a nonstructural measure will reduce emergency costs is a difficult task.

The costs should be determined by a survey of emergency expenses incurred in recent floods, both in the study area and regionally, and a statistical analysis of the relationship between these costs and floodplain occupancy (Water Resources Council, 1979). A simple regression model relating emergency costs and variables representing occupancy could yield an equation to estimate emergency costs more appropriately than using arbitrary percentages of physical damage estimates. Further discussion of emergency costs is provided in Appendix B.

Income Losses. Floods often interrupt, or disrupt, business activities causing a loss of income to the firm and/or loss of wages to workers. To the extent that these losses are not recovered by postponing the activity or performing it at another establishment outside the floodplain, they represent losses in income to the nation. An inundation reduction benefit is created when a flood loss mitigation measure prevents or reduces the losses by making it possible for the activity to continue during floods. For example, a manufacturer operating at full capacity twenty-four hours a day may have electric equipment susceptible to flooding, forcing the plant to close for the duration of floods. If the entire industry is operating at capacity, the loss of output by the manufacturer is a loss of national output. A benefit would result from implementing a nonstructural measure which would allow the plant to operate during the flood event thereby eliminating the income loss.

An inundation reduction benefit due to income loss reduction must be carefully justified and will only be valid in specific instances. Estimation of

this benefit should be based on specific survey or economic data (Water Resources Council, 1979). Conditions of the industry and of the individual firm are very important in determining when this benefit exists.

"Other" Costs. Three additional subcategories of inundation reduction benefits have been identified (Water Resources Council, 1979). They are: reduction in flood insurance overhead, restoration of land values and savings in floodproofing costs. Reduction in flood insurance overhead occurs when a measure reduces the flood hazard removing the need for flood insurance for some floodplain residents. Savings in administrative cost are for the flood insurance policies which were in effect in the without condition but are no longer necessary as a result of the measure. The measure must remove the need for each policy by removing the flood hazard to the property or by reducing the occupants' perception of risk to the point where insurance is no longer considered necessary. The benefit is calculated by multiplying the flood insurance industry's average overhead per policy by the number of policies which would no longer be in effect after implementation of the measure. This is not overhead in the conventional sense of the term which means fixed costs but it is the per policy cost of administering flood insurance--the variable cost which can be saved by cancelling the policy. Fixed costs are costs which remain the same regardless of the number of policies outstanding. For example, if an existing structure were raised to remove the flood hazard, prompting the occupant to cancel his flood insurance policy, then the overhead cost of administering that policy would be saved.

Restoration of land values by allowing more efficient use of existing activities and structures in the floodplain may also be claimed as a benefit. For example, if an industrial structure is not being used as intended because of the flood hazard, and implementation of a flood mitigation measure allows fuller utilization, the resulting increase in net income may be claimed as a benefit. Restoration of land values is different from intensification benefits. Restoration of land value occurs when increasing the full existing productive capability of an activity (that is, bringing it up to its existing potential) to be used when the flood hazard had limited that use. Intensification benefit

results when a flood loss reduction measure allows an activity to modify or intensify its existing use of the floodplain.

Savings in floodproofing costs occur when a flood mitigation measure allows new structures to be built in the floodplain without incurring costs associated with FIA regulations (e.g., the cost of elevating a new structure). This benefit is limited to structural measures since none of the nonstructural measures can bring about savings in floodproofing costs.

Benefits from reduction in flood insurance overhead, restoration of land values and savings in floodproofing costs are limited in both scope and application for nonstructural measures. Only savings in flood insurance overhead is applicable to the nonstructural measures discussed in this report.

Intensification Benefits

Intensification benefits are increases in net income resulting when a commercial or industrial activity located on the floodplain without the plan modifies its operation because the reduction in flood hazard makes it profitable to do so (Water Resources Council, 1979). If a flood control measure induces a modification in a commercial or industrial activity, the benefit is the excess of revenues over costs resulting from the modification since this is a net addition of income to the nation. The increase in market value of the land with intensified use or the direct increase in income from the new use may be used as a measure of the benefit. Both measure the same thing so the results may be compared but not added together (Water Resources Council, 1979).

For example, a small perimeter wall around a manufacturing plant may induce an expansion in production because of reduced flood risk. Facing the risk may have discouraged the owner of the floodplain plant from expanding and removal of the hazard allows the intensification. Intensification benefit for commercial and industrial activities is theoretically valid but empirically it is "primarily applicable to agriculture flooding" (Water Resources Council, 1979). The limit to the benefit is normally the increased flood damage potential of the intensified

over the existing activity evaluated in the without condition. Since the decision to intensify an activity in the floodplain is a function of the flood risk, only measures which reduce risk produce intensification benefits. Structural measures imply a broad reduction in flood risk and are therefore more likely to produce intensification benefits. Careful documentation and justification of intensification benefit for nonstructural measures is necessary.

Location Benefits

Location benefits are the difference between aggregate net incomes (including economic rent) which results when an activity uses the floodplain with a plan but not without it (Water Resources Council, 1979). Location benefits are the incremental net income which results when an activity is induced to locate on the floodplain and that location decision produces higher net income than an alternative site. For example, if a commercial facility would choose the floodplain location in the absence of the flood threat, removal of the flood risk will allow the preferred location. Net income from the preferred location must be shown to be higher than from the alternative location.

"The difference between estimated market value of the floodplain land with and without the plan can be taken as an estimate of the present value of the difference between aggregate net incomes" (Water Resources Council, 1979). The two market values represent the present value of the future stream of income produced on the land. Land with higher, or more productive, use will command a higher price. Market values of floodplain land will increase if implementation of flood loss reduction measures allows better use of the floodplain.

Three types of location benefits are possible. The first is the net income generated by the new use of the floodplain. A good example is use of the floodplain for public recreation--the benefit is the net recreation benefits measured in the usual way. The second is the increase in market value of lands adjacent to open space created by the flood management plan. This is an attempt to measure the externality of location adjacent to open space. Finally, when the plan includes removal and relocation of existing structures, a benefit equal to

the market value of the relocation site with the relocated structure can be counted (ER 1105-2-353, Corps of Engineers, 1978). Table 2-1 suggests a general format for displaying NED benefits.

Procedures and Assumptions for Evaluation of NED Benefits

Calculation of benefits for structural or nonstructural flood loss mitigation measures requires a substantial amount of information. "Procedures for Evaluation of National Economic Development (NED) Benefits and Costs in Water Resources Planning" (Water Resources Council, 1979), describes a ten-step evaluation procedure for gathering and analyzing necessary information. The first nine steps provide the necessary data and definitions to implement step ten which is the computation of NED benefits. Rather than reproducing the procedure here, it is suggested that the Water Resources Council document is an excellent reference for analysts faced with the task of evaluating NED benefits from nonstructural measures.

Level of Detail

Three stages of analysis are defined as part of the Corps of Engineer planning process (Corps of Engineers, 1975). ER 1105-2-200 defines stage 1 as development of the plan of study. The result of this stage is often called the reconnaissance report. Since the level of study is only introductory, it is not appropriate to require detailed data. The level of detail and specificity increases in stage 2 where intermediate plans are developed. Several iterations of the analysis may occur here in which inappropriate alternatives will be screened out. Stage 2 is a preliminary evaluation stage.

In stage 3, detailed plans are developed and the evaluation process is carried out in detail for a smaller number of alternatives. This report describes procedures for computing NED benefits which are conceptually sound. These procedures are the same for all stages of analysis. However, the level of detail of data will differ among the stages. Much less detailed information is required in stage 1 than in stage 3. For example, it may be sufficient to apply the analysis to groups in stages 1 and 2 but to individual structures in stage 3.

TABLE 2-1

NATIONAL ECONOMIC DEVELOPMENT BENEFITS SUMMARY

SWOLLEN CREEK FLOODPLAIN

	Measure		
Benefit Category	1	2	3
Inundation Reduction			
Physical Damage Reduced			
Reduction in Emergency Costs			
Reduction in Income Losses			
Reduction in FIA Administrative Cost			
Intensification			
Location			
New Uses			
Open Space Externality			
Market value of relocation site with evacuated structures			
TOTAL BENEFITS			

Source: Water Resources Council, 1979

The With and Without Condition

The benefit from a flood loss reduction measure is the resulting increase in net income to the nation on the floodplain. Determination of benefit is made by comparing net income in the with and without conditions. Careful analysis is necessary to project land use in the with and without conditions for each alternative measure. The without condition is defined to include the following:

1. Existing and authorized flood control plans. Benefits cannot be claimed for reducing damages which would have been reduced under these plans.

2. Land use regulations which can or will be certified under the Flood Insurance Program. Such regulations will have the following critical features: "no further development of the floodplain unless the lowest floor (including basement) of the building is elevated to the 100-year level for residences or floodproofed to that level for non-residences; no occupancy of the floodway fringe which when taken with other developments raise the height of the flood level by greater than one foot anywhere in the floodplain; and no occupancy of the floodway" (Water Resources Council, 1979). This implies that any activity which chooses to locate on the floodplain, and is allowed to, will incur costs of floodproofing. Residences must be elevated at least to the 100-year level and commercial or industrial structures must be floodproofed to at least that level. It further implies that a flood control program cannot claim as benefits those damages which will be reduced as a result of the land use regulation. Structural measures can produce benefits by removing the necessity to incur the floodproofing costs but nonstructural measures can only produce benefits by providing protection in excess of that required in the regulation. For example, a residence to be located in the floodplain is constructed on piers putting the first floor at the 200-year flood level. Even though the ground elevation may be the 5-year level, only the incremental damages prevented between the 100-year and 200-year elevations can be counted as benefits. This is because the damages reduced between the 5-year and 100-year elevation are assumed prevented by the land use regulation.

3. The life of existing structures. Careful analysis of structure life is necessary because benefits for damages reduced to an existing structure cannot be claimed after that life since the without condition assumes that the structure will be replaced with a structure which meets the requirements of the Flood Insurance Program.

The with project conditions are defined by the same assumptions plus an assumption of the useful life of the flood control measures to be undertaken. The with condition also includes all the provisions of the flood control alternative under consideration.

SECTION 3
MEASURES WHICH PERMANENTLY MODIFY THE DAMAGE SUSCEPTIBILITY OF EXISTING STRUCTURES

General Overview

The first category of nonstructural measures includes those which permanently modify the damage susceptibility of existing structures, contents and associated properties. Permanent implies the measures are continuously in place and require no action or only minimal action of floodplain occupants to make them effective. The following permanent measures modify the damage susceptibility of existing structures: 1) closures or sealing of openings; 2) raising structures; 3) perimeter barriers such as small walls or levees; 4) rearranging or protecting contents; and, 5) relocation of people, contents and/or structures. Other publications provide complete definitions of these measures (for example, Johnson, 1978).

Permanent closures, raising, perimeter barriers, and rearrangement of property are often referred to as floodproofing measures. Each measure modifies the stage-damage relationship by preventing damages to the structure and/or contents to the design level. Once the design level is exceeded the measures may have different stage-damage functions. For example, for perimeter barriers, floods greater than the design level result in inundation of the structure while for "raising" the stage-damage function is effectively shifted up. Other differences among floodproofing measures are well defined in the literature.

The remainder of this section discusses NED benefits from measures which modify the damage susceptibility of existing structures. Benefits from measures referred to as floodproofing are discussed first followed by a discussion of the benefits from relocation measures.

Floodproofing

Inundation Reduction Benefits

Physical Damage. Benefits result when a flood mitigation measure prevents or reduces flood damages. The damage reduction represents a net income gain in the NED accounts by reducing the cost of floodplain occupancy. Closures affect the stage-damage function by directly reducing damage to the interior of the structure and to contents. The protection is only in effect to the design level. Closures have no effect on damage to the exterior of the structure, to yards or to contents outside the structure. Assumptions about effectiveness of the closures in preventing seepage should be made explicit in the analysis. Once the design level is exceeded, inundation is assumed and the stage-damage curve regains its normal shape and height.

Raising an existing structure changes the stage-damage relationship by placing the first floor elevation at a higher stage. The stage damage function for the interior of the structure and contents begins at the new first floor elevation. Residual damage remains to yards, the underside of the floor, contents outside the structure, outbuildings, etc. The amount of residual damage would depend on the extent of changes related to raising the existing structure.

Perimeter barriers are designed to prevent damage to structures and contents to the design level. Damage to contents outside the wall, utilities and other public facilities remain. Once the design level is exceeded, inundation occurs and damages immediately reach the level expected without the wall.

Physical damage reduced from rearranging or protecting property is specific to structures and items of property. For example, if a washing machine and dryer are relocated from a basement or first floor to an upper floor damage is reduced because these property items are not susceptible to flood damage as they were at the lower level. Estimating physical damage reduction requires specific information about the structures and property (items) to be moved or protected. Different structures may have quite different results.

For floodproofing measures, physical damage reduction benefit is measured as the difference between damage with and without the measure. There is basically no difference between computation procedures for physical damage reduction for floodproofing and structural measures. The evaluation of floodproofing may require a structure and site specific analysis of changes in the stage-damage function. Damages reduced are summed in order to arrive at total physical damage reduced.

The assumptions of the without condition require careful accounting of structure life to be included in the analysis. Benefit claims of structures which would be replaced during the project life of the measure under consideration must consider the replacement structure to be elevated to the 100-year level for residences and floodproofed to that level for non-residences (Water Resources Council, 1979). Elevating of structures beyond the 100-year flood level would create benefits for the incremental physical damage reduced.

Emergency Costs. Emergency costs are defined as costs which result from emergency activities prior to, during and after a flood; for example, evacuation, floodfighting and public clean-up, respectively.

Emergency cost reduction benefits may be claimed when a flood loss mitigation measure reduces emergency expenses of floods which are not included in physical damages. For example, a valid case can be made for this benefit if a specific survey of the floodplain or other research shows the measure will reduce the costs of temporary evacuation, floodfighting or extra police and fire protection.

The analyst must estimate emergency costs by surveying and analyzing use of the floodplain, and likely emergency activities, not by applying a percentage to physical damages. The magnitude of emergency costs is a function of the pattern and extent of floodplain occupancy in the with and without condition. Specific floodplain occupancy information is required and an analysis of the effects of the nonstructural measure on activities during and after floods. Different measures affect emergency costs differently, but the measure of benefit is the difference between emergency costs compared with and without the measure.

Closures are structure specific and have little to do with reducing risk of flooding to public facilities and utilities or to evacuation efforts. Some floodfighting and clean-up costs may be reduced. Reduction in emergency costs should, therefore, be used as an inundation reduction benefit where specific data or analysis can be used to show such a reduction.

If raising existing structures can be expected to reduce emergency costs, then the reduction can be claimed as a benefit. However, if only one, or a few residential structures are raised the flood hazard may not be reduced enough to significantly affect emergency activities. Alternatively, a general program of raising structures and providing for access during floods, may eliminate the hazard and substantially reduce emergency costs. Raising will only affect those emergency costs related to structures, contents and occupants and will not reduce emergency costs to public utilities and other public facilities.

Perimeter barriers may eliminate the flood hazard to the design level and certain emergency activities, such as temporary evacuation, may then be unnecessary as long as the flood is below the design level. Reduction in these activities reduces costs. Walls or levees may also eliminate much of the clean-up and, under certain circumstances (e.g., when all of the structures in the floodplain are protected by walls) may reduce the need for floodfighting. Rearranging or protecting property does not change the flood hazard and is not likely to significantly affect emergency activities.

In general, emergency activities are broad in scope while most nonstructural measures are implemented on a small scale. With the exception of relocation, nonstructural measures will usually have a relatively small impact on emergency activity requirements.

Income Losses. Flood control measures which allow a business to continue operating during a flood, when that activity would not have been possible otherwise, create an inundation reduction benefit. The losses prevented are either wages or net profits of the business. In order to claim the benefit it must be shown that the activity could not be postponed or transferred to another facility

on or off the floodplain. An income loss benefit can be claimed for floodproofing if it can be shown, using independently derived economic data (Water Resources Council, 1979), that the floodproofing will prevent an income loss. For example, a lumber mill in the floodplain must discontinue operation anytime the flood elevation exceeds a certain level. The mill operates at full capacity twenty-four hours per day, but in flood events above the critical level the mill closes for the duration of the flood plus approximately eight hours for clean-up and restarting of machinery. Since the mill operates continuously at full capacity, production lost cannot be postponed. The remainder of the industry is also at full capacity so the production cannot be transferred. If floodproofing raised the critical elevation, the income losses between the old and new elevations for the duration of the flood plus eight hours would be prevented. These income losses would be calculated as revenues minus operating costs for the estimated time period.

This benefit is difficult to document because it requires specific independent economic data and because of the nonpostponement and nontransferability requirements. Agricultural activities, protected by a structural measure, provide the best example of an income loss benefit. For example, in the without condition, a flood of a certain stage and duration will inundate a crop and cause it to fail. The farmer loses income because he can neither postpone nor transfer that crop to another location. A flood control measure which prevents the inundation prevents the income loss. No empirical examples were found in industry other than agriculture. It is conceivable that any of the floodproofing measures could reduce income losses and such a benefit can be claimed if the proper documentation is provided. The most likely of the floodproofing measures to produce this benefit is perimeter barriers because the results are similar to those of structural measures. The benefit is measured by the difference between income losses with and without the flood mitigation measure.

Intensification Benefits

Intensification benefits result when a commercial or industrial activity which exists in the with and without condition is intensified in response to

reduced flood damage. The benefit is the increased net income in the with condition. Floodproofing an existing commercial or industrial structure may create intensification benefits if that activity is modified or expanded as a result of the reduced flood risk to the raised structure. The analyst must show that the flood control measure will induce the intensified activity and that net income will be increased. For example, an existing industrial firm could produce a product which is complementary to its existing product lines but which is very susceptible to flood damage while held in inventory. If the firm's existing warehouse could be floodproofed and the firm subsequently expand into this new and profitable product line, an intensification benefit would be produced. The key here is the relationship between the expansion or modification and the flood control measure--this is true for all structural and nonstructural measures--there must be cause and effect.

Measurement of intensification benefits can be by direct comparison of estimated revenues and costs in the with and without condition or by comparing estimated market values with and without the measure. In either case, the analyst should carefully document intensification benefits with specific economic information.

Any of the floodproofing measures can create intensification benefits except for rearranging or protecting contents. Rearranging or protecting contents within an existing structure reduces flood damage to that piece of property but does not reduce the hazard of flooding and thus would not induce a more intense use of the floodplain by an existing activity.

Location Benefits

Floodproofing to modify the damage susceptibility of existing structures cannot produce location benefits because, by definition, location benefits require different land uses in the with and without condition.

Relocation

Permanent relocation measures are designed to remove the damage potential from threatened floodplain areas by evacuation of people and personal property. Structures may be either relocated or demolished. The evacuated floodplain is restored for flood compatible use or for open space and may either be developed by the agency or sold with an encumbered title. Relocation differs from other nonstructural measures because it is not an attempt to maintain and protect existing uses but to reduce flood damage by removal of the damageable property. Benefits are measured somewhat differently and evacuation constitutes a separate subcategory of measures which modify the damage susceptibility of existing structures.

Inundation Reduction Benefits

Physical Damage. Relocation reduces all of the damage associated with the removed activities. Damage to existing and remaining roads, public utilities and communication systems would remain. Relocation benefits are defined as: "the net income earned by activities occupying the floodplain with the project plus that portion of the flood damages reduced by the project which is not borne by the without-project floodplain occupants" (Corps of Engineers, 1978). The benefits to be measured are the increases in net income which result from that portion of damage reduced which the without project floodplain activities have externalized, e.g., emergency costs and other costs borne by the public, not the floodplain occupant.

Relocation removes damage to existing structures but average annual damage reduced cannot be used as a measure of project benefits because some of that damage is reflected in the market value of the structure. The damage reflected in the market price is that which is borne by the floodplain user. The remainder of the damage is externalized, i.e. borne by the public. Since damage reduced is counted as a benefit for floodproofing, the treatment of benefits from relocation appears to be different. However, a cost of relocation is the purchase of the structure being damaged but this is not a cost of floodproofing. The market

value of the structure is lower by an amount which theoretically reflects the flood damage which the occupant will incur over the life of the structure. Since this damage is capitalized into the market value and reflected in the lower purchase price it should not be counted again on the benefit side of benefit-cost analysis as damage reduced. If both were included, the damage reduced with evacuation would be included as a benefit and purchase of the lower market value structure as a cost. This would be double counting.

Damage which is externalized (i.e., paid by someone else) is not reflected in the purchase price. The reduction in this externalized damage is a legitimate inundation reduction benefit because it reflects the reduction in what the public pays for flood damages. The measure of externalized flood damage has two components: insurable flood damage and flood insurance overhead. Reduction, or savings, in these two components result in benefits.

For communities which participate in the Federal Flood Insurance Program or are expected to participate without the project, a relocation plan may bring about a savings in insurable flood damage. This is an inundation reduction benefit. Insurable flood damage represents the amount of public (i.e. external) compensation for private flood damage incurred. Since this damage is reimbursed, it theoretically is not reflected in the reduced market value of the floodplain structure. To determine the benefit, insurable flood damage must be calculated separately.

Using the characteristics of the floodplain and flooding in the projected without condition and traditional depth-damage-frequency relationships, total damage can be projected over the life of the project. The analyst should take account of the life of existing structures. Where the life is shorter than the project life and the structures would be rationally moved they should be moved in the analysis. The analyst should also be careful to incorporate any other dynamics of floodplain land use which have been identified. Structure life and floodplain dynamics should, of course, be taken into account in the analysis of any flood mitigation measure.

To calculate insurable flood losses, "projected total damages are reduced by subtracting: 1) losses which are non-insurable either because they are not in insurable loss categories or they exceed the coverage limits of the subsidized programs" (Water Resources Council, 1979). For example, the coverage limit for single family residential structures is $35,000 per structure and $10,000 for contents in the emergency program. If projected total damage exceeds the coverage limits, insurable flood losses are reduced by this excess because these uncovered losses are theoretically reflected in the market value of the structure; 2) the deductible portion of each expected flood damage event; and 3) the annual cost of the premium paid by the policy holders (Water Resources Council, 1979). The actual premium is less than the actuarial rate by the amount of the subsidy which represents the taxpayers' contribution to the flood insurance program. Equation (3-1) summarizes the calculation of insurable flood losses.

$$IFL = TFD - NL - D - SP \qquad (3\text{-}1)$$

where:

IFL = insurable flood loss
TFD = total flood damage
NL = noninsurable losses
D = deductible
SP = subsidized premium

Total flood damage is reduced by the noninsurable portion of the loss, by the deductible and by the actual premium paid on the insurance policy (i.e., either the emergency rate or the actuarial rate reduced by the subsidy), all of which are assumed to be reflected in the lower market value of the structure. For example, emergency program rates are $0.25 and $0.35 per $100 of residential structure and contents, respectively, so a $30,000 structure with $10,000 in contents would pay an annual premium of $110.

Reductions in flood damage reflect the portion of the projected damage which would be paid by the floodplain occupant, the remainder is the portion of the damage to be covered by the flood insurance. In actual practice, average

annual insurable damage would be computed over the project life with noninsurable losses and the deductible subtracted from each event. The actual premium paid on an annual basis would reduce the average annual insurable loss.

The calculations are made on the assumption that the subsidized flood insurance program covers all eligible structures because market values of floodplain properties reflect the availability of flood insurance and not actual purchase of the policies (Water Resources Council, 1979).

The overhead costs of administering the flood insurance program are an additional cost of flooding not borne by the floodplain occupant. Reduction in these externalized costs is therefore a benefit of the relocation measure. The benefit is calculated by multiplying the average overhead cost of the flood insurance program by the number of flood insurance policies in effect in the without condition. For insurable flood damages it is assumed that all structures are covered but that assumption is dropped for this calculation. The cost "should be determined based upon average cost per policy including agent commission servicing and claims adjusting costs" (Water Resources Council, 1979). The Flood Insurance Administration is the appropriate source of data on these costs.

Emergency Costs. Other costs of occupying the floodplain which are not borne by occupants but which are reduced by relocation can be claimed as benefits. These include: emergency evacuation costs, floodfighting costs and costs of repairs to public facilities and utilities due to floods. These costs must be empirically determined as a function of past floods and floodplain occupancy and not as an arbitrary percentage of damage. Emergency activities would no longer be necessary after evacuation of the floodplain since the old activities are replaced by flood compatible activities. Emergency costs would therefore be reduced significantly by relocation.

Income Losses. Flood loss mitigation measures can create NED benefits by reducing income losses. The reduction must be net, i.e., the losses cannot be transferable to another location or establishment, or postponable. Assuming that this falls under the same proviso as other damage reduction, evacuation

with relocation creates benefits in this category only to the extent that such income losses are externalized. For example, if the losses were covered by flood insurance then insurable losses, or that part externalized, would be the applicable benefit.

Under current conditions income losses would be borne solely by the floodplain activity and relocating the activity would reduce potential income losses but not externalized losses. Losses borne by the floodplain activity would be capitalized in the market value of the property and evacuation would not result in an income loss reduction benefit.

Intensification Benefit

Intensification benefit is the increased net income of a floodplain activity which is the same in the with and without condition but whose operation is modified in response to the reduction in potential flood damages. Relocation cannot create intensification benefits since the floodplain use is different in the with and without conditions. Removing structures and activities does not allow for modification to produce increased income from the existing floodplain use.

Location Benefit

A location benefit exists when an activity uses the floodplain in the with but not the without condition and this results in an increase in net income. The measure of the location benefit is the increase in net income of the activity over what it would have been in the without condition at an alternative site off the floodplain. The category of location benefit allows a project, or flood mitigation measure, to create benefits by bringing about a locational advantage on the floodplain. Where such a locational advantage is created, net income on the floodplain in the with condition will be higher than it would have been in the without condition at the next best location off the floodplain. Practical measurement of location benefit for relocation is in three subcategories:

Net Income of New Floodplain Uses. After evacuation, the floodplain may

have several potential flood compatible uses. If a public use of the floodplain is projected for the evacuated floodplain, potential users' willingness to pay represents the increased income of the project. There are several methods for measuring the recreation benefit including the user day and travel cost methods (Water Resources Council, 1979).

The benefit of private rather than public use of the floodplain after evacuation is the projected market value of the floodplain site if sold with an encumbered title (i.e., a title which restricts the floodplain to certain uses or manner of use--for example, the title could specify only agricultural or open space uses). The market value represents the capitalized NED net income to be expected from the potential floodplain uses. The market value estimate must take explicit account of potential uses of the floodplain, floodplain characteristics and activities which could use the floodplain advantageously under the restrictions imposed by the title. This category of benefits may be very important in the feasibility of evacuation and relocation measures in urban floodplains.

Value of Externalities Created When Relocation Results in Open Space. Externality is defined to be the increased economic value (or decreased value in the case of pollution) which results from an activity but which is captured outside the market. For example, a residential structure located adjacent to an relocated floodplain will experience the resulting open space without paying for it. The measure of this location benefit is increase in market value of land which is adjacent to open space[1] after the evacuation is complete but which did not have the advantage of this location before evacuation. This is the basis for including the value of open space externalities as a subcategory of location benefit--the benefit results in the with condition because the adjacent landowner uses the floodplain as open space when he does not use it in the without condition.

[1]It is important to note that abandoned floodplains if not maintained may result in negative location benefits because of problems caused by weeds, trash and etc.

The projected increase in market values must be empirically documented. For example, by showing statistically that sites adjacent to existing open space have higher market value than equivalent sites which are not adjacent to open space. A regression could be tested which relates market value to site characteristics including proximity to open space. If the resulting coefficient of open space is statistically significant, the model could be used to estimate market values of adjacent lands after the evacuation. The investigator should be careful to specify the model so that open space does not become a proxy for some other variable such as proximity to schools or shopping. Other statistical precautions should be taken to insure the value of open space is actually being measured.(See, for example, Johnson, 1978.) Direct recreation benefits which accrue to occupants of adjacant lands counted as net income of new floodplain uses must be netted out to avoid double counting. In other words, if the market value is increased because of the recreation this increase must be separated from the increase due to externality.

In practice, estimating the value of externalities may be difficult for two reasons. First, substantiating any increased market value of adjacent lands brought about by open space is difficult because many factors determine land value and separating them statistically has not been completely successful. Most progress has probably been made in relating market values and water quality in streams (c.f. Epp and Al-Ani, 1979). Second, separating recreation benefits from the increased market values due to open space externality may require a very sophisticated model and primary data gathering.

Market Value of Relocation Sites. When structures are physically relocated, a benefit may be claimed "equal to the market value of the relocation sites with the relocated structures" (Corps of Engineers, 1978). Apparently, this provision is to allow the capture of benefits created by relocating floodplain structures and thus increasing the value of the relocation sites. The cost of the site is included as a cost of the project and the value of the relocation site is included to offset this cost. Projections of market values of relocation sites are based on empirical examination of likely sites and land values. Evacuation of floodplain land may increase the value of nearby suitable land since the

effective supply of such land may be reduced. (See, Office of the Chief of Engineers, 1979, for an exposition of estimating market value of land.) When structures are not relocated the value of salvageable material may be used to reduce the cost of the relocation measure.

	INUNDATION REDUCTION BENEFITS	
Item	Reduction in Physical Damage	Reduction in Emergency Costs
Description of Measure	Reduction in damage to structures, contents; property, cost of clean-up; damage to roads, bridges, sewers, power lines and etc. Measured using conventional depth-damage-frequency relationships.	Reduction in expenses of floods not included in physical damage, including: evacuation, reoccupation; floodfighting; provision of communication; increased cost of police and fire protection; costs of extra security. Measured by specific survey or research and not as an arbitrary percentage of physical damage.
Floodproofing		
Permanent Closures Raising Existing Structures Perimeter Barriers Rearranging or Protecting Property	May claim inundation reduction benefits for physical damage reduced.	Reduction in emergency costs may be claimed as a benefit.
Relocation	This measure may claim only reduction in externalized damage, measured as: IFL = TFD - NL - D - SP (1)	Reduction in emergency costs may be claimed as a benefit.

TABLE 3-1

YING DAMAGE SUSCEPTIBILITY OF EXISTING STRUCTURES
NATIONAL ECONOMIC DEVELOPMENT
BENEFIT CATEGORIES

TS		INTENSIFICATION BENEFITS	LOCATION BENEFITS
osts floods damage, eoccupa- vision sed pro- pecific ot as of	Reduction in Income Losses Reduction in losses of wages or of net profits to businesses which result from disruption caused by flooding. Losses must be not postponable or transferable to another location or establishment. Documentation requires specific independent economic data.	Increase in net income to a commercial or industrial activity when it modifies or expands its operation as a result of the flood mitigation measure. The activity must exist in both the with and without condition but be intensified in the with condition.	Increase in net inco which locates in the result of the flood The measure must cre advantage for the ac floodplain is differ without conditions. measured by the cha of the floodplain si the increased insom
osts may	A benefit for income losses reduced may be claimed if properly documented.	These measures reduce the flood hazard and may allow for intensification benefits.	None of the measure floodplain land use are not applicable.
		The hazard is not changed so intensification benefits are not applicable.	
osts may	Income losses not covered by insurance may be claimed if properly documented.	Land use is different in with and without conditions so intensification benefits are not applicable.	Where the evacuated eloped for public u are created in the benefits (e.g., rec Location benefits of location adjace also be created.

3-1
ITY OF EXISTING STRUCTURES
MIC DEVELOPMENT
ATEGORIES

	INTENSIFICATION BENEFITS	LOCATION BENEFITS
Income Losses losses of wages fits to busi- result from used by flood- must be not r transferable cation or . Documentation ific independent .	Increase in net income to a commercial or industrial activity when it modifies or expands its operation as a result of the flood mitigation measure. The activity must exist in both the with and without condition but be intensified in the with condition.	Increase in net income to an activity which locates in the floodplain as a result of the flood mitigation measure. The measure must create a locational advantage for the activity. Use of the floodplain is different in the with and without conditions. The benefit may be measured by the change in market value of the floodplain site or directly as the increased insome.
income losses e claimed if mented.	These measures reduce the flood hazard and may allow for intensification benefits.	None of the measures induce a change in floodplain land use so location benefits are not applicable.
	The hazard is not changed so intensification benefits are not applicable.	
not covered may be claimed ocumented.	Land use is different in with and without conditions so intensification benefits are not applicable.	Where the evacuated floodplain is redeveloped for public use, location benefits are created in the form of public use benefits (e.g., recreation benefits). Location benefits due to the externality of location adjacent to open space can also be created.

SECTION 4
MANAGEMENT OF FUTURE DEVELOPMENT

The second general category of nonstructural flood mitigation measures includes those which manage future development. These measures have been widely implemented but primarily at the state and local level. Measures in this category reduce flood damages by influencing future location decisions to reflect the flood hazard or by modifying the damage susceptibility of those structures which do locate in the floodplain. Measures in this category include: 1) regulatory actions to manage land use in the floodplain; 2) purchase of land or easements to manage land use in the floodplain; 3) physical measures which modify the damage susceptibility of future structures in the floodplain; and, 4) regulatory actions implemented for off floodplain development to control runoff which might result in increased downstream flood hazard in the future. For example, regulation to prohibit future development, or to control the nature of future development, so that the flood hazard is maintained at its present level.

Regulation of floodplain land use may take a number of different forms but operates primarily in two ways. First, regulatory activity may attempt to cause land use decisions to more realistically reflect the flood hazard. Flood insurance, taxation and floodplain information programs all make the potential floodplain occupant more aware of the flood hazard so the location decision can be made with more complete information. Flood insurance further acts to indemnify floodplain occupants for losses and to provide an indicator (premiums) of which locations are more floodprone. Taxation is the only active policy in this group. Placing higher taxes on floodprone lands discourages development by making off-floodplain land relatively less expensive.

Second, regulatory activity may control location directly or may control the manner in which development takes place. Zoning, land use restrictions and urban planning actively control the type and location of activities on the floodplain. Subdivision regulations, building codes and related regulatory activities control the manner in which structures are built. These regulations, for example, may require elevating for all new structures within the 100-year floodplain. They

may also require water resistant materials and other flood hazard compatible construction practices.

Future development may also be controlled by direct purchase of either land or flood easements in the floodplain. On a floodplain which has open space (or only few existing structures), acquisition in fee or of an easement can insure that future land use is compatible with the flood hazard. Public acquisition for open space has the same result as zoning to prevent development.

The future damage susceptibility of structures which will be located on the floodplain in the without condition can be modified by the application of physical measures to the new structure. These measures are the same as those applied to existing structures except that they are incorporated directly into the construction of the new structure. Measures include elevated construction either on piers or fill, floodproofing (for example, construction of a commercial structure of masonry with the lower floor sealed) and by using materials and construction practices which reduce the potential damage to the structure. Physical measures are most often taken in response to zoning ordinances or other regulatory actions but the measures can also be undertaken privately in response to the perceived flood threat. In either event, the measures reduce future damages from floods.

The final measure in this category is regulation of land use off the floodplain. Development at higher elevations near a floodplain may affect the runoff characteristics of stormwater and change the flood hydrology on the floodplain. Stormwater management systems include storm sewers, conveyance conduits, detention storage and pumping facilities (Davis, 1974). These systems must be evaluated in the context of the communities which they serve but the planning of both the community and the stormwater management system should be evaluated in terms of their effect on the floodplain as well. Without proper planning, development off the floodplain may raise the 100-year flood level leading to damage to all those structures which were built to reflect the before off-floodplain development 100-year flood. For example, land use regulations may require structures to be elevated three feet in a particular floodplain to place the first floor elevation above the 100-year flood level. Development off the floodplain occurs

and the 100-year flood level rises to four feet causing increased damages to all those structures built under the regulation. Management of off-floodplain development then mitigates potential future damages by preventing the 100-year flood level from rising.

The Flood Disaster Protection Act of 1973 (PL 93-234) is one of several laws developed because flood damages continued to grow even with significant efforts and expenditures in flood control. This Act requires floodplains which desire to participate in the flood insurance program to have a floodplain regulation. The required regulation precludes new development within the floodplain unless "the lowest floor (including basement) of the building is elevated to the 100-year flood level for residences or floodproofed to that level for non residences." This defines the without condition and provides a context for evaluation of measures which affect future development. A nonstructural mitigation measure applied to future development generates benefits only for those damages reduced above the 100-year flood level. Benefits of the regulation required in the without condition are assumed at least equal to the costs.

The following sections explain the evaluation of NED benefits for these management measures. In general, these measures only create inundation reduction benefits if damages, emergency costs or income losses are reduced below what they would be under the regulations prescribed for the without condition by the Flood Disaster Protection Act, i.e., for damage reduced beyond the required 100-year protection level. The measures do not create intensification benefits because floodplain land use is different in the with and without condition. Location benefits are also not created because a location advantage is not created by the management measures.

Inundation Reduction Benefits

Physical Damage. Measures which manage future development in the floodplain produce benefits when damage is prevented or reduced over and above that which would exist in the without condition. Reduction in damage increases net income in the NED account because it decreases the costs of floodplain occupancy. The

measure of benefit is the difference between physical damage with the measure and physical damage without the measure but with the required level of protection defined by the Flood Disaster Protection Act (PL 93-234).

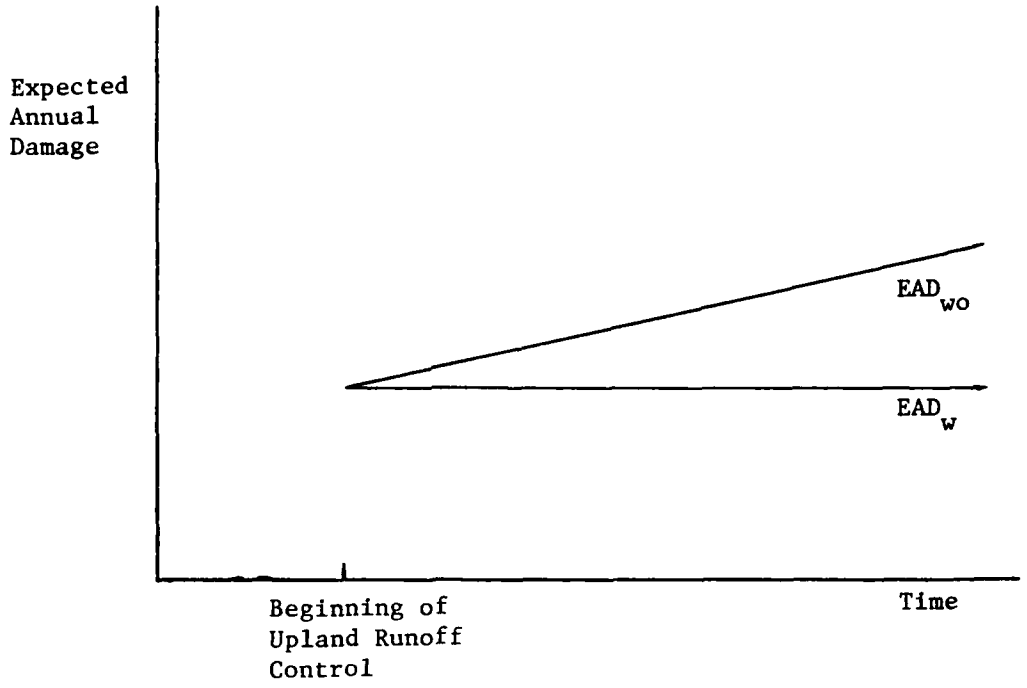
Inundation reduction benefits result when damages are reduced and the floodplain land use is the same in the with and without condition. Measures which manage future development by changing land use do not create inundation reduction benefits but those measures which result in physical changes being made to expected future development can create inundation reduction benefits. These physical changes can be initiated by regulatory actions, such as zoning ordinances, restrictions and building codes, which require future floodplain structures to physically modify their damage susceptibility. Physical measures undertaken in the absence of regulations will also create these benefits. In both cases, only reductions in excess of that which results when complying with PL 93-234 may be counted (Water Resources Council, 1979).

Regulation or acquisition which precludes development of the floodplain prevents damages to structures and contents which would have located there. However, the regulation also prevents the increase in net income which floodplain location would imply. Rational location on the floodplain means that the benefits of location there outweigh the costs, including the cost of damage due to flooding. Exclusionary zoning prevents the damage but prevents the positive benefit of the location as well and no physical damage reduction benefits should be claimed. For acquisition, the purchase price of the floodplain land is lower to reflect the susceptibility to damage so to count damage reduced as a benefit would be double counting.

Management of runoff from future development in upland areas off the floodplain may create inundation reduction benefits by preventing increases in future flood flows. For existing development upland runoff control creates benefits by reducing damage which would occur as the flood flows increase in the absence of the control. Figure 4-1 illustrates the effect on expected annual damages (EAD) with and without the measure. EAD_{WO} represents the EAD which are expected to grow over time as a result of increased flooding if future upland development is

FIGURE 4-1

EXPECTED ANNUAL DAMAGE WITH AND WITHOUT UPLAND RUNOFF CONTROL



not managed to control runoff. EAD_w represents damages with upland runoff management. The difference between EAD_{wo} and EAD_w is the inundation reduction benefit. The shape of both EAD_w and EAD_{wo} depends on the effectiveness of the runoff management measures, the nature of existing development, and upon the timing and nature of future development.

For any new development on the floodplain, increased flood flows implies an increased level of flooding for the 100-year event. New development is required by regulation to be protected (by raising or floodproofing) to the 100-year flood level. If the 100-year flood level is based on present estimates of runoff from off floodplain development then increased development off the floodplain will raise the 100-year flood level causing damage to floodproofed structures. Management of the future upland development runoff can prevent this increased damage and create inundation reduction benefits. Alternatively, if present estimates of the 100-year flood level are based on projections of future development off the floodplain then managing that upland development will lower the 100-year flood level. Savings in floodproofing costs between the two 100-year flood levels is an inundation reduction benefit. If upland runoff is not controlled there will be a gradual reduction in the level of protection in the future.

Emergency Cost. An emergency cost reduction benefit results when those costs of floods which are not included in physical damages are reduced in the with condition as compared to the without condition. Emergency costs in the without condition are those which would occur with the expected amount and type of development in the future. All of the future development is assumed to meet the required FIA regulation.

Management measures require protection above that required by the FIA regulation and will reduce emergency costs if the flood hazard is reduced enough to reduce emergency activities during floods. For example, raising a structure to a level higher than the 100-year flood may reduce the need for emergency evacuation for floods between the 100-year and the higher level. The probability of flood occurrences greater than the 100-year level are small which implies that

the difference in emergency costs between with and without conditions will also be small unless the floodplain is densely developed. Only this difference may be counted as a benefit.

Where regulation or acquisition precludes development it eliminates emergency costs by preventing structures from occupying the floodplain and the necessity for emergency activities during floods. The measure of benefit is the difference between total emergency costs reduced and the emergency costs reduced by implementation of elevation or protection to the 100-year level as required by the FIA regulation.

Regulation of off floodplain land to control runoff may also reduce emergency costs. If the stormwater runoff management imposed by the regulation results in less runoff or less intense runoff because stormwater is handled more efficiently, the emergency activities during a flood may be reduced. Analysis of the specific effect of the measure on flows would be necessary to determine if any emergency activities could be reduced.

It is important to point out again that estimates of emergency cost reduced cannot be obtained using an arbitrary percentage of physical damage reduced (Water Resources Council, 1979). Specific analysis of the effect on emergency activities in the context of the projected future development on the floodplain is necessary.

Income Losses. Floods can disrupt the normal activities of a business causing it to incur losses. If a flood control measure allows that business to continue operating then those losses can be avoided. This reduction in losses is counted as a NED benefit if specific independent economic data show that the loss could not have been avoided by either postponing the activity until after the flood or transferring the activity to another location.

Projected floods may cause an income loss to a commercial or industrial activity even if it is protected to the required 100-year level. A physical measure, whether voluntary or required by regulation, to modify the damage

susceptibility of the new structure (e.g., elevating it to a level greater than required) can reduce that loss and create a benefit. This benefit would be measured as the income losses with the assumed 100-year level protection minus income losses with the higher level of protection. Although it is conceivable that such a benefit could exist, it is likely to be very small since the probability of flood events in excess of the 100-year level is small. Careful documentation and independent economic data is always required to show the existence of the income loss and that it is not postponable or transferable.

Regulation which precludes development in the floodplain prevents activities from locating there whose revenues would exceed the costs of floodplain occupancy including potential income losses. Rational location decisions imply that an income loss reduction benefit cannot be claimed for this type of zoning. Since preventing development prevents both the income loss and the potential for producing income by the activity on the floodplain, public acquisition would also not create an income loss reduction benefit.

Regulating off-floodplain development to control runoff may reduce income losses by reducing expected increases in flood flows. For all these measures, documentation of an income loss reduction benefit requires careful economic analysis.

Intensification Benefits

Intensification benefits result when a commercial or industrial activity which exists in both the with and without conditions is modified as a result of a flood control measure. Measures which manage future development deal with new structures while intensification benefits result from modified use of existing structures so no benefits result.

Location Benefits

When a flood control plan induces a new activity to use the floodplain and aggregate net income of the affected area is increased, a location benefit is

created. The key concept is that the plan or measure induces the activity to locate on the floodplain and higher net income results.

Regulations requiring structures which locate on the floodplain to undertake physical measures to modify their damage susceptibility and the physical measures themselves do not create location benefits. In order to create location benefits a flood control measure must induce an activity to locate on the floodplain when it otherwise would locate somewhere else. In effect, the measure is giving the floodplain location an advantage over other sites by reducing the costs of the activity. Does a measure such as elevating a structure above the 100-year level induce location on the floodplain? Requiring the structure to be elevated adds to the costs of a location decision already made. The measure is not inducing the location and does not increase the net income of floodplain activities. No location benefits accrue to the measures.

Regulation which precludes development and acquisition of floodplain land to be used as open space or sold with an encumbered title may result in location benefits. If either of these measures result in a new use of the floodplain and that use increases net income, this is a location benefit. For example, the income of land acquired fo a park, measured by its recreation benefits, would be a location benefit just as the location benefits result from development of recreation on an evacuated floodplain. The measurement of the benefit would be either as the value of its public use or as the market value of the land in its new use. If land use regulation or public acquisition prevents future development and preserves open space then the market value of land in open space can be claimed as a benefit. The result of exclusionary regulation or public acquisition could be negative location benefits if the uses of the floodplain which are precluded would have produced a higher net income (after subtracting expected flood damages and floodproofing costs). This, in fact, seems to be the likely case if rational location decisions are assumed and if the expected use of the floodplain in the without condition is not open space. Since the guidelines for benefit measurement (Water Resources Council, 1979) do not deal with the issue of negative location benefits further discussion of the issue is beyond the scope of this report.

Regulation of runoff from upland areas off the floodplain may create location benefits if the reduction in future flood flows is sufficient to induce an activity to locate on the floodplain. Table 4-1 summarizes the applicability of the various categories of benefit to the measures which manage future development.

TABLE 4-1
MANAGING FUTURE DEVEL

NATIONAL ECONOMIC DEVELOPMENT BE

INUNDATION REDUCTION BENEFIT

Measure	Reduction in Physical Damage	Reduction in Emergency Costs
Regulation		
Requiring Modification of Damage Susceptibility of New Structures	Claimable	Claimable
	Flood damage Without[2] (100-year) - Flood damage With (>100-year)	Emergency Cost-Without[2] (100-year) - Emergency Cost-with (>100-year)
Preventing Development	Not claimable	"
Acquisition of Land or Easements	Not claimable	"
Floodproofing Measures for New Structures	Claimable	"
	Flood damage Without (100-year) - Flood Damage With (>100-year)	
Regulations for off-floodplain development to control runoff.	Claimable	"

[1]See Table 3-1 for descriptions of categories of benefit

[2]The without condition assumes the FIA required regulation.

TABLE 4-1
G FUTURE DEVELOPMENT

DEVELOPMENT BENEFIT CATEGORIES[1]

UCTION BENEFITS		INTENSIFICATION BENEFITS	LOCATION BENEFITS
ergency Costs	Reduction in Income Losses		
	Claimable	Not claimable	Not claimable
mergency Cost-with (>100-year)	but not likely to be significant		
	"	"	Claimable for value of land in new use
	"	"	"
	"	"	Not Claimable
	"	"	Not Claimable

SECTION 5
FLOOD PREPAREDNESS PLANS

General Concepts

A flood preparedness plan is a complex group of related temporary actions designed to mitigate flood losses. The plans consist of predetermined functional arrangements and emergency actions which are implemented on a response basis during floods. Preparedness plans can enhance other measures, structural or nonstructural, or provide a way to reduce damage until permanent measures are implemented. Preparedness plans may be considered alone or as an element of other measures either existing or proposed. The plans are oriented toward reducing catastropic losses and social disruption occurring with rare flood events. The principal components of flood preparedness plans are: preparedness plans

- early recognition of flood threat
- dissemination of flood warnings
- emergency response actions
- recovery and reoccupation of flood areas
- continuous management of the flood preparedness plan

Development of flood preparedness plans on a community level and the successful implementation during a flood event requires a high degree of communication, cooperation and coordination between a broad range of public and private organizations and the general public. Inter-jurisdictional efforts between cities and counties are frequently required in successful actions during floods.

Decisions as to the type and scale of emergency actions to be implemented are based on numerous considerations associated with the nature of the specific event. Among these are: the nature of the flood event (magnitude, duration, etc.); warning time; public awareness; and resource and materials availability. The final effectiveness of the actions are also based on the above considerations.

The following paragraphs define the five components of flood preparedness plans and then the benefits are discussed.

Recognition of Flood Threat. Recognition of flood threat requires some means for prediction of an impending flood, including those of weather forecasts, precipitation and/or streamflow measurements, transmission of collected data, and processing and interpretation of collected data. The various elements comprising this component must be specifically designed to enable the accuracy and timeliness in warning which is appropriate to the area to be protected. The procedures and means employed for flood threat recognition may vary significantly in type and sophistication depending upon the characteristics of the stream system, nature of the area at risk and other factors. For example, principal approaches to flood threat recognition include: computerized systems featuring telemetric querying or signaling capability between gages and a mini-computer equipped with a rainfall-runoff model for prediction of flood information; various water level sensing devices which signal when stream levels reach some predetermined stage; and networks of observers who take direct readings of precipitation and river stages and forward the information to some central location for processing and interpretation.

Dissemination of Flood Warning. Dissemination of the flood warning to floodplain occupants provides the link between recognition of an impending flood and execution of the emergency response actions. It consists of three main parts: provisions for decision on whether or not a warning should be issued; procedure for formulation of the warning message; and procedures and means for actual distribution of the message to affected parties by means of radio, television, sirens, bullhorns, door-to-door notification, etc. For maximum effectiveness, the procedures and means for warning dissemination must provide for reaching each individual who could be directly affected by the impending flood with a message stating the time available before flooding occurs and its expected severity, and describing appropriate response actions (evacuation routes, safe destinations, protective measures, etc.).

Emergency Response Actions. Objectives of emergency response components of

a preparedness plan vary according to the completeness of the plan. Minimal plans are usually limited to measures for the safety and welfare of people, more comprehensive plans also address reduction of damages associated with flooding, while complete plans include provisions for the reduction of losses other than direct damages. Emergency response elements of preparedness plans normally deal with: search and rescue of endangered people; temporary evacuation of threatened areas; temporary relocation (removal or raising) of movable public and private property; floodfighting efforts; and management of important services and facilities such as those related to electric power, gas, water supply, sewage collection and disposal, fire suppression, law enforcement, and emergency medical service. Portions of the preparedness plan dealing with those matters ordinarily consist of predetermined strategies for coping with one or more levels of flooding and the assignment of responsibility for their timely execution.

Postflood Recovery/Reoccupation. Postflood recovery/reoccupation component of preparedness plans deals with steps and resources necessary to return the community to normal status as rapidly as possible after a flood episode and mitigate secondary problems occurring in the postflood period. Specific matters usually addressed in the postflood recovery/reoccupation component include: the return to normal operation of important services and facilities, steps to prevent unsafe reoccupation of endangered structures, and identification and provision of assistance to the general public and local governments.

Continuous Plan Management. Preparedness plans consist largely of organizational and institutional arrangements. Without periodic use, such arrangements are likely to become obsolete and/or unimplementable. The continuous plan management component provides for the necessary actions on a periodic basis to maintain the viability of the plan during the period between flood episodes. Continuous plan management involves: updating of those portions of the plan subject to obsolescence such as telephone numbers, assignments of responsibility, etc.; provisions for maintenance and testing of equipment; and educational and informational activities including training of anticipated participants in plan execution, conduct of exercises and drills, conduct of public awareness programs, and education of the public with respect to actions to be taken during the floods.

Benefits. Determining benefits for flood preparedness plans is somewhat more complex than determining benefits for other nonstructural measures because the five components are interdependent. Early recognition is crucial to providing adequate warning time to allow floodplain occupants to take emergency response actions. To keep the preparedness plan operational the plan must be continuously managed. Weakness in any component will affect all the others and the resulting benefits.

Evaluation of flood preparedness plans is further complicated by technical problems (Owen and Wendell, 1978). For example, meteriological forecasts are often unreliable. Response to warnings and the amount of damage thereby reduced depends on the sociological framework of the community, its historical setting and many other factors (McLuchie, 1970). This means that response can only be predicted with uncertainty and therefore that benefit prediction will be subject to uncertainty.

Flood preparedness plans do create NED benefits. In particular, the emergency response actions reduce physical damages and a well developed plan has the potential to create both location and intensification benefits. The next few paragraphs will discuss the procedures for measuring these benefits.

Inundation Reduction Benefits

Physical Damages. Benefits result when a measure prevents or reduces physical damages to structures and/or contents thereby producing a gain of net income in the NED account. Flood preparedness plans reduce damage by emergency response. Specific actions include temporary closures or seals, relocating damageable contents either within the structure or outside the floodplain (e.g., moving a sofa from a basement family room to an upper floor or removing a vehicle from the floodplain). The effectiveness of the emergency response actions depend on receiving and responding to a warning, time of day, public awareness, amount of time since last flood, and etc. Longer warning times, for example, implies a larger reduction in damage.

The measure of inundation reduction benefit is the difference between damages with and without the preparedness plan. Determining this benefit requires site and structure specific information to determine the potential effectiveness of the response actions. Emergency response in terms of damage reduced, persons evacuated, etc., can only be convincingly established using actual response data from floods at locations with preparedness plans. The benefits must be substantiated based upon real data. A probability distribution of warning times and the probability of receiving the warning could be combined with damages reduced for the structure at various lengths of warning to develop an expected value of damages reduced at each flood stage. The relationship between the frequency of flood and probability of early warning would need to be determined for the specific floodplain. This is a rather complex process.

Emergency Costs. Flood preparedness plans do not change the flood hazard but may make emergency activities more efficient and effective, thereby reducing the costs of these emergency activities. A benefit for emergency cost reduction is only possible where an improvement in the efficiency or effectiveness of emergency activities results in measurably lower emergency costs. Appendix B briefly discusses the relationship between preparedness plans and emergency costs.

Income Losses. Flood preparedness plans may make it possible for a commercial or industrial activity to avoid the disruption which would otherwise occur during floods. If the plan allowed effective implementation of temporary floodproofing measures, such as closures, which prevented flood waters from stopping production, the income losses which would have otherwise occurred are prevented. Generally, plans for commercial or industrial activities will be justified by the reduction of income losses to the specific firm and where this is the case the preparedness plan will be private. Income losses must be documented with careful economic analysis which shows that the loss cannot be postponed or transferred to another location.

Reduction in FIA Administrative Cost. Flood preparedness plans may reduce the premium on flood insurance for floodplain occupants but it will not reduce

FIA administrative costs which are only saved if a flood loss mitigation measure results in cancelled policies. No benefit can be claimed.

Intensification Benefit

The increased net income of a floodplain activity which modifies its operation in response to a flood control plan is the intensification benefit. The measures included in flood preparedness plans are temporary and give the occupant more time to adjust to an impending flood. This could conceivably result in intensification of an activity and an intensification benefit. Claiming the benefit requires a careful economic analysis and documentation.

Location Benefit

If an activity is induced to choose a floodplain location by a plan, the increased net income which results is a location benefit. Any structure to be located on the floodplain in the future is assumed to have 100-year protection as required by the FIA certifiable regulation. The incremental advantage that a commercial or industrial establishment might gain from implementation of a flood preparedness plan is very small since preparedness plans are oriented to rare events which have only a small probability of occurring. As a result, a preparedness plan could create a locational advantage for floodplain location and location benefits are claimable. Careful documentation and justification are required to claim these benefits.

Table 5-1 summarizes the discussion of the applicability of NED benefit categories to flood preparedness plans. The components of a plan are not listed in the table as separate measures because they are interdependent. Implementation of response actions require warning which requires flood recognition. Only the response actions actually create benefits but these can be legitimately attributed to the entire plan because of the interdependence of the components.

TABLE 5-1

SUMMARY OF NED BENEFITS
FLOOD PREPAREDNESS PLANS

Benefit Categories[1]	Measures Flood Preparedness Plans
Inundation Reduction	
Physical Damages Reduced	Claimable
Reduction in Emergency Cost	Claimable
Reduction in Income Loss	Claimable
Reduction in FIA Administrative Cost	Not Claimable
Intensification	Claimable
Location	Claimable
New use	Claimable
Open space externality	Not Claimable
Market value with encumbered title	Not Claimable

[1]Descriptions of the benefit categories appears in Table 3-1.

APPENDIX A
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APPENDIX B

FLOOD PREPAREDNESS PLANS - EMERGENCY COSTS

The relationship between flood preparedness plans, which are made up primarily of temporary or emergency measures, and the subcategory of benefits called emergency costs is not clear. This appendix will discuss emergency costs, preparedness plans and other nonstructural measures to clarify the relationship which exists among them.

Savings in emergency costs are a benefit because NED net income is increased when the costs of coping with floods are decreased. This subcategory of benefits was developed in the context of structural measures which have a significant impact on emergency costs because of their large scale and broad effect on flood waters. Preventing the flood removes the necessity for emergency actions until the structural measure is overtopped. Structural measures do not remove the need for being prepared for floods greater than the design level but do remove the necessity for emergency actions during flood events less than the design level. Overall emergency actions undertaken at the community level are reduced because of the effect of the structural measure on the flood waters and the flood threat.

Nonstructural measures, on the other hand, are generally implemented on a smaller scale. Nonstructural measures applied to existing structures can be implemented on a lot, block or neighborhood basis and the scale of protection is not the same as structural alternatives. The effects of these nonstructural measures may not be to significantly reduce the need for broad scale emergency actions on the community basis. As a result, only a small reduction in overall emergency costs can be attributed to nonstructural measures. The analysis of the benefit requires that the specific effect of the nonstructural measures on emergency activities be determined.

Flood preparedness plans are temporary or emergency measures for which decisions of implementation are made on an event basis. Scale and type of emergency measure to be undertaken are determined by, for example, warning time, nature of flood events, and etc. An important element of flood preparedness

plans is emergency actions. These are the same emergency actions which are reduced by structural and some nonstructural measures to produce benefits. Can flood preparedness plans produce benefits by increasing emergency activities?

This question leads to a further question -- should reduction in emergency costs be counted as an inundation reduction benefit? Emergency activities are undertaken because the results justify the actions. Floodfighting, temporary relocation and other emergency actions reduce damages of floods. The benefits presumably outweigh the costs or floodplain occupants would not undertake the actions. In evaluating the emergency cost reduction benefit, it is only appropriate to count emergency cost reduced if the physical damage which would be reduced by those actions is not also reduced by the measure. The basic concept is that only the net amount of saving is counted as benefit.

Preparedness plans produce these inundation reduction benefits because elements of the plans do reduce damages of floods.

This whole question of emergency cost reduction benefit and evaluation of benefits from preparedness plans is worthy of further study. Evaluation of preparedness plans may require tools of analysis different from those used for other measures. Simulation studies, for example, may provide a basis for projecting the effectiveness, and resulting benefits, of preparedness plan elements.

APPENDIX C
A PROCEDURAL EXAMPLE

Purpose

This appendix is provided as an illustration of the benefit evaluation concepts and procedures described in the text of the report. The examples do not stand alone but must be read in the context of the report. The floodplain communities and numbers used in the example are hypothetical but an attempt was made to produce an example realistic enough to illustrate the procedures and some of the difficulties that might be encountered. A number of Corps of Engineers project reports were examined and personnel contacted but most of the example was developed from scratch since experience with nonstructural flood mitigation measures is not yet extensive enough to provide data from completed analyses or projects.

Three reaches of the Swollen Creek floodplain are used in the example. The first contains an existing community, Spring Creek, which has a number of structures. Spring Creek and measures applied to its structures are used to illustrate the calculation of benefits for nonstructural measures which modify the damage susceptibility of existing structures.

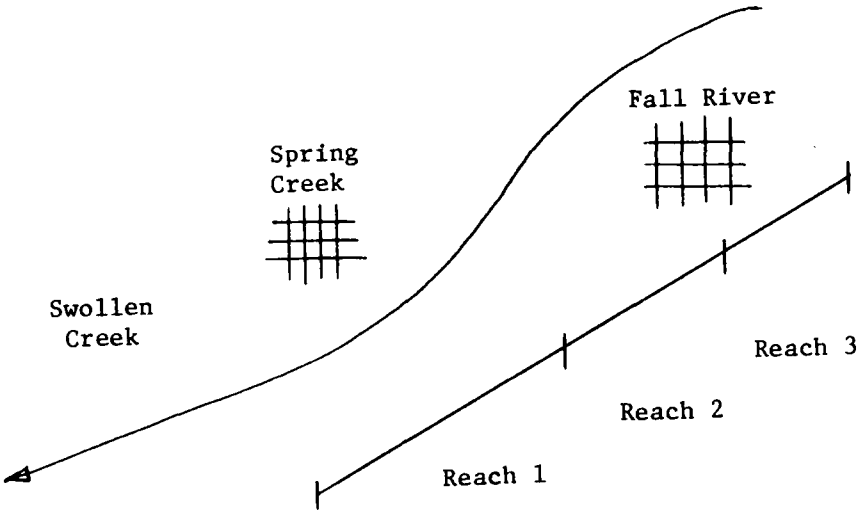
Reach 2 is presently undeveloped but is expected to develop in the future. This reach is used to illustrate calculation of benefits for nonstructural measures which manage future development. Reach 3 contains the community of Fall River which has one residential, one commercial and one industrial structure. Fall River is used to illustrate the benefit measurement procedures for preparedness plans.

Background

Flooding is a serious problem in the communities of Spring Creek and Fall River. Both lie at least partially within the floodplain of Swollen Creek. Figure C-1 shows schematically the two communities and the remainder of the

FIGURE C-1

SWOLLEN CREEK FLOODPLAIN



study area which is presently undeveloped. The plan formulation process determines the number, elevation, value and other characteristics of both existing structures and structures projected on the floodplain in the future.

Spring Creek has twenty-one structures in the floodplain at various elevations. Fifteen of the structures are residences, four are commercial establishments and two are industrial plants. The area away from the river side of this small community rises abruptly and is naturally protected from flooding. The discussion of Spring Creek is based on procedures for evaluating benefits from nonstructural measures which modify the damage susceptibility of existing structures.

Several alternative flood damage mitigation alternatives have been evaluated and one alternative to be evaluated is nonstructural. Table C-1 shows the type and location of structures within the 100-year floodplain together with the nonstructural measure for which NED benefits are to be evaluated. Physical feasibility is an important consideration in nonstructural formulation but will not be evaluated here.

Reach 2 of the Swollen Creek floodplain is the area between Spring Creek and Fall River and is presently undeveloped. The area is expected to urbanize and encroach on the floodplain. Projections of future land use have been developed using steps 1 through 5 of the Water Resources Council evaluation procedure (Water Resources Council, 1979). Residential, commercial and industrial activities are expected to locate in various parts of the reach. Since the floodplain is in the flood insurance program, land use regulations are in effect which preclude future occupancy of the floodplain unless elevated to the 100-year level for residences and floodproofed to that level for non-residences. Existing land use plans and regulatory policies divide the floodplain into residential, commercial and industrial areas. Table C-2 shows the extent and type of development projected in the without condition.

Reach 3 is the community of Fall River and is used to illustrate the evaluation of benefits for preparedness plans. Occupancy of the floodplain,

TABLE C-1

STRUCTURES AND NONSTRUCTURAL
MEASURES TO BE EVALUATED

SWOLLEN CREEK
REACH 1

Structure Type and Location	Nonstructural Measure to be Evaluated
Residential	
10 structures below 25-year flood elevation	Evacuate
3 structures between 30-year and 50-year elevation	Raise
2 structures between 50-year and 100-year elevation	Small perimeter levee
Commercial	
3 structures (masonry)	Permanent closures
1 structure	Relocate utilities and damageable inventory to upper floors
Industrial	
1 structure	Combination of closures and a small wall
1 structure	Demolish and reuse floodplain for compatible use

TABLE C-2

PROJECTED FLOODPLAIN LAND USE
SWOLLEN CREEK
REACH 2

Structures[1]	Residential		Commercial		Industrial
	Area 1	Area 2	Area 3	Area 4	Area 5
Residential (number of structures)	10	5			
Commercial (number of establishments)			2	1	
Industrial (number of plants)					2
Open space (acres)	2		1		1

[1]All structures projected are assumed to be either elevated or floodproofed to the 100-year flood level as required by the FIA regulation.

location of structures and the nature of the flood problem are important in determining the effectiveness, and therefore the benefits, of preparedness plans. For simplicity, the community of Fall River is assumed to have 10 residential structures, one commercial and one industrial structure. The following paragraphs summarize the benefit calculations for the three reaches.

Reach 1 (Spring Creek) - Existing Structures

Residential. Referring to Table C-1, several nonstructural measures to modify damage susceptibility of existing structures are to be evaluated. Ten residential structures are to be evacuated and relocated or demolished. The ten residential structures are identical except for foundation and at the same elevation. The calculation of insurable flood damages assumes the availability of flood insurance for all the structures. Only seven of the structures are actually covered so the reduction of Flood Insurance Administration overhead reflects only seven rather than ten policies. The evacuation is of a cluster of homes covering approximately five acres adjacent to the rest of the city. Two acres of the evacuated area will be developed into a small park and playground while the other three acres will be sold with an encumbered title which will allow only flood compatible uses. Table C-3 details the calculation of insurable flood damages for the evacuation/relocation measure.

Evacuation may enhance the value of properties which become adjacent to open space. This benefit would be estimated by determining the increased market value of the properties which results from the open space externality. Claiming such a benefit requires documentation of the increased value of the adjacent properties compared with similar properties which do not experience the externality. No benefit is claimed for this here but this does not imply that it should not be estimated in floodplains where it can be documented by careful economic analysis.[1]

Emergency activities will no longer be necessary for the ten evacuated

[1]Documentation of methods for evaluating open space externalities is beyond the scope of this report.

TABLE C-3

CALCULATION OF "INSURABLE FLOOD DAMAGES"
FOR $60,000 STRUCTURE WITH $30,000 CONTENTS VALUE (AVERAGE STRUCTURE)

SWOLLEN CREEK
REACH 1

Average Annual Damages		$7000
Noninsurable losses (average annual)		
To yards, etc.	$ 100	
Over coverage limits[1]	1200	
Deductible[2]	100	
Premium	532	
Total		-1932
Insurable Flood Damages		$5068

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[1]Coverage limits for single family residential are $185,000 for structure and $60,000 for contents but here we assume that occupants choose to insure only 80% of the value of the structure and its contents.

[2]$400 per event for the life of the project is equivalent to $200 average annual deductible.

[3]Subsidized rates are $.25 and $.35 per $100 of structure and contents value. Actuarial rates for flood zones A8-A14 and first floor elevation at three feet below the base flood elevation (i.e., below the 100 year event) are $0.935 and $2.06 per $100 of structure and contents value, respectively. (The source for these rates is Flood Control for Santa Fe, U.S. Army Engineer District, Albuquerque, 1979 but the FIA rate schedules should be used in actual studies.) Premiums are calculated as follows (if 80% of value is insured):

	Structure		Contents	
Subsidized	.25 x 35,000/100 =	$ 87.50	.35 x 10,000/100 =	$ 35
Actuarial	.93 x 13,000/100 =	120.90	2.06 x 14,000/100 =	288.40
		$208.40		$323.40

Total = $532 (if 80% of value is insured)

residential structures. Average annual emergency costs are reduced by the amount of these costs which were directly associated with the structures. The emergency cost estimate is developed by empirically examining costs of emergency activities in floods of record on Swollen Creek and on similar floodplains.

Damage to utilities will be eliminated except for damage to utilities for the park and to the new floodplain use. Damages to utilities are also determined by looking at past floods. Five of the evacuated structures are on conventional foundations and can be relocated while five are on slab foundations and it is not feasible to move them. The estimated market value of the relocation sites with the structures that can be moved is added to benefits. The small park generates recreation benefits estimated by the user day method to be $300 annually. The park will be primarily used as a playground for children. The remaining three acres are available for sale with a title which requires flood compatible use. The value of this land is a benefit and for this project the value is established at that for comparable flood free land. Table C-4 summarizes the benefits from evacuating the residential structures.

Five additional residential structures are within the floodplain at Spring Creek, three are to be raised and small perimeter levees are to be built around the other two. Both measures are categorized as floodproofing and benefits are limited to inundation reduction benefits. Benefits are measured as damages without less damages with the project. Briefly, the procedure is as follows: 1) determine existing flood damage (using step 6 of the evaluation procedure (Water Resources Council, 1979); 2) compute expected annual damage; 3) modify the damage susceptibility of the structures; 4) recompute expected annual damage after modification; 5) enter the difference between the expected annual damage as physical damage reduced; 6) determine the extent which emergency costs may be reduced as a result of the measures; and 7) determine whether any income losses will be prevented by the measure. The benefits are estimated using as much information about future conditions in the floodplain as possible. Expected growth in value of contents and changes in hydrology are incorporated into the estimates. Increased market value of the structure is assumed to be capitalized in the current market price.

TABLE C-4

SUMMARY OF BENEFITS FROM RESIDENTIAL EVACUATION

SWOLLEN CREEK
REACH 1

Category	Benefits	
Inundation Reduction		
Reduction of Insurable Damages	$50,680	
Reduction of FIA Overhead[1]	70	
Reduction of Emergency Costs	500	
Reduction of Income Losses	0	
Reduction of Damages to Utilities, etc.	200	
Total Inundation Reduction Benefits		$51,450
Intensification	0	0
Location		
Market Value of Relocation Sites With Structures (5 relocated)[3]	17,800	
Recreation Benefits from New Park	300	
Market Value of Land with Encumbered Title[2]	750	
Total Location Benefits		18,850
Total NED Average Annual Benefits		$70,300

[1]Seven structures have flood insurance policies and average overhead is estimated to be $10 per policy. This is not overhead in the normal sense of the word--usually defined as fixed costs--but the variable cost of servicing each policy.

[2]Estimated using $3000 per acre as value of land for open space use annualized over 50 years at 7 3/8% (the official Corps discount rate is expected to be 7 3/8% by the time this report is distributed). This is approximately $225 per acre on an annual basis.

[3]Estimated at $50,000 per structure and remaining life of 50 years at 7 3/8%.

No significant changes in emergency activities are expected as a result of these residential floodproofing activities therefore no benefits result from the measures. Income losses of businesses are not affected by the measures, either.

Although intensification benefits are zero in this example it is possible that intensified use of a residential structure could result from a nonstructural measure. For example, a small wall or levee might make an otherwise unusable basement into a recreation room. The wall could still be overtopped but the extra time provided by the wall's protection would allow movement of the furniture from this newly developed room to an upper floor. Estimating the value of this modified use would require an estimate of the increased market value of the structure with the recreation room. Location benefits for floodproofing residential structures are also zero since no floodplain location is induced. Table C-5 summarizes the NED benefits for floodproofing residential structures at Spring Creek.

Commercial and Industrial. From Table C-1 it can be seen that evaluation of floodproofing for four commercial and one industrial structure is required. The same seven steps suggested above for evaluating residential floodproofing are appropriate here. Physical damages can be reduced and a reduction of emergency costs results from reduced floodfighting due to floodproofing the industrial plant.

The industrial structure is a strategic plant in an industry which is operating at full capacity now and will be expected to be at least fifty percent of the time in the future. Floodproofing reduces income losses which result from disruption due to floods and approximately fifty percent of these losses cannot be recovered at another time or another location. No location benefits occur but the industrial structure and one commercial activity are able to modify or intensify their use of the structure producing intensification benefits. Table C-6 summarizes the benefits from commercial and industrial floodproofing at Spring Creek.

TABLE C-5

SUMMARY OF BENEFITS FROM RESIDENTIAL FLOODPROOFING

SWOLLEN CREEK
REACH 1

Category	Benefits	
Inundation Reduction		
Physical Damages Reduced	$4000	
Reduction of Emergency Costs	0	
Reduction of Income Losses	0	
Reduction of Damages to Utilities, etc.	0	
Total Inundation Reduction Benefits		$4000
Intensification		0
Location		0
Total NED Average Annual Benefits		$4000

TABLE C-6

SUMMARY OF BENEFITS FROM COMMERCIAL AND INDUSTRIAL FLOODPROOFING

SWOLLEN CREEK
REACH 1

Category	Benefits	
Inundation Reduction		
Physical Damages Reduced		
Commercial	$10,000	
Industrial	3,600	
Reduction of Emergency Costs	300	
Reduction of Income Losses[1]	1,000	
Reduction of Damages to Utilities, etc.	0	
Total Inundation Reduction Benefits		$14,900
Intensification		
Commercial	1,500	
Industrial	2,500	
Total Intensification Benefits		4,000
Location		0
Total NED Average Annual Benefits		$18,900

[1] Documented by an in-depth economic study of this industry and the role this specific plant plays in the industry's total production.

One industrial structure is to be demolished and the site sold with an encumbered title. This plant is nearly obsolete and is subject to high levels of damages at relatively low depth of flooding. In addition, surrounding properties have been developed to be more compatible with the flood threat by being elevated or otherwise constructed to reflect the flood hazard. Calculation of insurable flood damages for this industrial structure follows the same basic procedures as the calculation for residential evacuation/relocation. The calculations are shown in Table C-7. No intensification benefits occur but location benefits can be claimed equal to the market value of the evacuated land sold with an encumbered title. Table C-8 summarizes the benefits from industrial evacuation.

Reach 1 flooding problems are handled with a combination of measures which modify the damage susceptibility of existing structures. Total benefits for these measures in Reach 1 is $114,300.

Reach 2 - Managing Future Development

A nonstructural flood loss mitigation plan is formulated to further manage the future development in Reach 2 of the Swollen Creek floodplain. Projected floodplain land use is presented in Table C-2. The plan calls for more stringent codes for residential structures built in Areas 1 and 2, for part of Area 5 to be an extension of projected open space for a flood water detention area, and for purchase of parts of Area 2 and of an easement for an additional 2 acres of open space in Area 4. The acquired portion of Area 2 is for expansion of the suburban park while the easement in Area 4 will provide for maintaining an existing ponding area. Regulations to control runoff in a future subdivision in an upland area off the floodplain is also included. Table C-9 summarizes the plan for management of future development.

Future flood damages are estimated and these are stated in average annual terms in Table C-10. These estimates reflect the required 100-year level of protection. Also shown in Table C-10 are estimates of average annual emergency costs and income losses expected for the future development. Both estimates are

TABLE C-7

CALCULATION OF "INSURABLE FLOOD DAMAGES" FOR AN INDUSTRIAL STRUCTURE
(STRUCTURE VALUE $200,000 CONTENTS VALUE $200,000)

SWOLLEN CREEK
REACH 1

Average Annual Damages		$20,000
Noninsurable Losses (Average Annual)		
Property outside structure	200	
Over coverage limits[1]	1000	
Deductible	100	
Premium[2]	3070	
Total		-4,370
Insurable Flood Damages		$15,630

[1]The property is insured for $100,000 structure value and $150,000 contents value.

[2]For this example assume Zone A15-A17 and first floor elevation two feet below base flood elevation. The example rates are $0.79 and $1.52 per $100 of structure and contents value insured (U.S. Army Engineer District, Albuquerque, 1979).

TABLE C-8

SUMMARY OF BENEFITS FROM INDUSTRIAL EVACUATION

SWOLLEN CREEK
REACH 1

Category	Benefits	
Inundation Reduction		
Reduction of Insurable Damages	$15,630	
Reduction of FIA Overhead	70	
Reduction of Emergency Costs	100	
Reduction of Income Losses	0	
Reduction of Damages to Utilities, etc.	0	
Total Inundation Reduction Benefits		$15,800
Intensification		0
Location		
Market Value of Land with Encumbered Title[1]		5,300
Total NED Average Annual Benefits		$21,100

[1]Market value of $70,000 amortized over 50 years at 7 3/8%. Two methods can be used to establish the $70,000 market value. Surrounding flood free land values less appropriate floodproofing costs or the value of similar open land subject to the FIA requirements may be used.

TABLE C-9

PLAN FOR MANAGEMENT OF FUTURE DEVELOPMENT

SWOLLEN CREEK
REACH 2

Measure	Residential		Commercial		Industrial
	Area 1	Area 2	Area 3	Area 4	Area 5
Regulation					
Requiring floodproofing or raising to the 250-year level (number of structures)	10	3			
Preventing development (number of structures)					1[a]
Acquisition of land or easements (acres)		1[b]		2[c]	
Floodproofing measures (structures)			1[d]		
Off Floodplain Regulations	Ten acres in an upland area which are expected to be subdivided for residential structures				

[a] Approximately five acres.

[b] Preventing construction of 2 residential structures.

[c] Preventing the construction of a commercial establishment.

[d] One commercial structure will be protected to the 250-year level by a combination of a small levee and permanent closures.

TABLE C-10

AVERAGE ANNUAL DAMAGES FROM FUTURE DEVELOPMENT

SWOLLEN CREEK
REACH 2
(Without Condition)

Structures	Residential		Commercial		Industrial	Total
	Area 1	Area 2	Area 3	Area 4	Area 5	
Residential[1]	3000	1500				4500
Commercial[2]			2500	750		3250
Industrial[3]					7700	7700
Emergency Costs						1000
Income Losses[4]						0
Total						$16,450

[1]The residential structures are assumed to incur approximately $300 each in average annual damage. The most likely is estimated for each of the future structures and this averages to $300 per structure.

[2]One commercial structure in Area 3 was estimated to incur $1500 EAD even with floodproofing while the other structure in Area 3 was estimated to incur $1000 and the structure in Area 4 $750.

[3]Plant A in Area 5 incurs $5000 in EAD while Plant B incurs $2700.

[4]Neither plant is in an industry characterized by full capacity utilization.

based on an analysis of likely events during floods and the specific characteristics of this reach and on historic floods both on Swollen Creek and similar floodplains. Expected damages are low because the without condition has the required land use regulation.

Damages are reduced by those actions which further modify the damage susceptibility of the future structures. The resulting decrease in average annual damages is small because the damages are associated with floods which occur with only small probability. The same is true with other categories of inundation reduction benefits--since the bulk of damages have been prevented by the protection realized from the FIA certified regulation, further reductions are small.

Table C-11 shows reduction of the expected annual damages to the various floodplain uses with the floodplain management plan. Only the damages reduced for those floodplain uses which are the same in the with and without condition should be in Table C-11 because this is required by the definition of inundation reduction benefits. However, regulation or acquisition operate in much the same way as evacuation/relocation of existing structures. The structures will exist in the projected without condition but are "removed" by the floodplain management plan. The benefit of preventing a structure from locating on the floodplain includes the insurable flood damage reduction and any reductions in emergency cost by removing the structure. Damages in the with condition reflect this treatment of structures prevented from locating on the floodplain. Management of runoff from future development off the floodplain creates benefits by preventing growth in flood flows. Total benefits in Reach 2 are $7835 annually.

Reach 3 (Fall River) - Preparedness Plans

There are several structures within the 100-year floodplain of Reach 3 of the Swollen Creek floodplain. An alternative nonstructural plan is the institution of a computer assisted flood preparedness plan designed to provide early recognition and warning of impending floods and a comprehensive plan of response. The effectiveness of the plan depends on the length of warning time, the probability that floodplain occupants will receive the warning, and the

TABLE C-11

NATIONAL ECONOMIC DEVELOPMENT BENEFITS

SWOLLEN CREEK
REACH 2

Benefit Category	Measure				
	Regulation		Acquisition	Floodproofing New Structures	Managing Runoff in Upland Subdivision
	By physical measure	By preventing development			
Inundation Reduction					
Physical Damages Reduced	$1000[a]	$2000[d]	$1160[b]	$1200	$200[g]
Reduction in emergency costs[c]	300	200	75	150	25
Reduction in Income Losses	0	0	0	0	0
Intensification	0	0	0	0	0
Location					
In new use	0	1225[e]	300[f]	0	0
With encumbered title	0	0	0	0	0
Total NED Benefits	$1300	$3425	$1535	$1350	$225

[a]Damages with the required 100-year protection less damages with the higher 250-year flood level protection.

[b]Insurable flood damages of $160 per residential structure, of $800 for the commercial structure, plus $10 in overhead reduced per structure.

[c]Emergency cost reductions were estimated by projecting the impact of changed occupancy on floodplain activities.

[d]$1900 in insurable flood damage plus $100 FIA overhead.

[e]Estimated using $3000 per acre as the value of land for open space annualized over 50 years at 7 3/8% or approximately $225 per acre.

[f]Estimated $4000 per acre for open space recreation land annualized over 50 years at 7 3/8% or approximately $300 per acre.

[g]Reduced damages because 100-year event elevation is not increased due to increased flood flows from runoff.

resulting response of occupants. Length of warning may vary among floods, The probability of receiving the warning and responding will differ for different lengths of warning time. In addition, the probability depends on time of day, or night, whether the flood comes on a weekday or weekend and on a number of other factors. This probability distribution depends on sociological and historical factors, such as whether or not the occupant has responded unnecessarily to false warnings in the recent past. The analyst should be careful to document the assumptions of the analysis and gather the information by survey or empirical analysis of floodplains with similar occupancy.

For simplicity it is assumed that there are only ten residential, one commercial and one industrial structure in this reach. More structures would not change the nature of the analysis nor to the explanation provided by the example. Careful analysis of each of these structures indicates that average annual damages could be decreased by the amounts shown in Table C-12 if warning for every flood were given in the time specified. The expected reduction in average annual damage is shown in Table C-13. The preparedness plan does not create benefits in any of the other benefit categories in reach 3 of the Swollen Creek floodplain. Total benefits of this measure are $21,090.

The difficulty in developing an example for preparedness planning points up some of the difficulties which may be encountered in evaluating a preparedness plan in a real project. Definition of the measure and its results is difficult because preparedness plans will vary among floodplains. Individual components of the plans will be different and the interaction of the components will also be different. In addition, the results of the plan are not easily predictable as other measures are. If a structure is floodproofed the change in physical damage is easily determined because we know what the floodproofing does and how it will reduce damages.

This example assumes that a relationship between warning time and damage reduced can be determined. This relationship allows an estimate of the benefits to be made. Total benefits from the three reaches of Swollen Creek are estimated to be $143,225.

TABLE C-12

AMOUNT OF PHYSICAL DAMAGE REDUCED WITH DIFFERENT WARNING TIMES

SWOLLEN CREEK
REACH 3
(Dollars)

Warning Time (hours)	Average Annual Damage Reduction		
	Residential	Commercial	Industrial
1	50	500	1000
2	75	600	1300
3	90	650	1400
4	100	700	1450
5	105	725	1480
6 or more	110	750	1500

TABLE C-13

SUMMARY OF NED BENEFITS

SWOLLEN CREEK
REACH 3
(Dollars)

Benefit Category	Residential	Commercial	Industrial
Inundation Reduction			
Physical Damages Reduced	$885	$6525	$13,680
Reduction in Emergency Cost	0	0	0
Reduction in Income Losses	0	0	0
Reduction in FIA Administrative Cost	0	0	0
Intensification	0	0	0
Location	0	0	0

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